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LATE BLIGHT OF POTATOES AND ITS CONTROL

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LATE BLIGHT OF POTATOES AND ITS CONTROL

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Late blight is one of the most widely distributed diseases affecting the potato, and, when conditions are favourable for its development, the most destructive. Explorers brought the potato from South America to Europe in the sixteenth century, where, in time, it became the staple food of the common people; but nearly 200 years passed before the late blight disease was recorded. It is thought that the malady was introduced at a later period, probably about 1830, on potatoes brought in from Mexico. When once established, the disease spread widely and caused great loss. For example, in Ireland, climatic conditions were favourable for the development and spread of the disease in 1845, and again in 1846. In both years, a severe epidemic occurred, resulting in almost the complete destruction of the potato crop. Famine overtook the people, and great numbers of them were forced to migrate to North America. By that time, the disease had already become widely established there. Down through the years since then, potato late blight has taken a heavy toll in many countries. It is usually less prevalent and destructive in moderately dry regions than in more humid ones, and in dry seasons than in wet ones. With the development of modern and efficient methods of combating the disease, it should no longer be a limiting factor in potato production, for assuredly severe losses from it can be prevented.

Symptoms of Late Blight

When once the grower becomes thoroughly familiar with the nature and symptoms of late blight, much of the mystery about its behaviour disappears. Like most diseases, it is recognized by the expression of its own particular characteristics. It is called late blight because usually it is most severe and causes the greatest damage late in the growing season. Generally it makes its first appearance later than does the leaf spot, known as early blight.[1] Late blight attacks the leaves, stems, and tubers.

On the Leaves, it appears as dark brown dead or dying areas which develop most frequently, but not always, near the edge or tip of the leaf and spread inwards, the rate of advance being most rapid when the weather is warm and moist. The immediate margin of the invaded area appears to be water-soaked, a typical symptom that can be detected more readily when the leaf is held against the light. The progress of the disease in the leaf tissue is further marked by light green zones surrounding each brown area. A characteristic sign of the presence of this disease is the development of a greyish mildew, or mould, on the under surface of the affected leaf area, which is more conspicuous when the plants are damp with dew or rain, or when the humidity of the air is high. This fine greyish mildew is composed of the reproductive (or fruiting) organs of the fungus. Numerous spores, the minute bodies capable of establishing the disease on other leaves and plants, are produced on these thread-like organs.

On the Stem, the water-soaked appearance is less marked than on the leaves, and the blotches are seen as blackened strips running lengthwise of the stem. On these also, spores are produced when moisture conditions are favourable.

[1] Caused by the fungus *Alternaria Solani* (E. & M.) J. & G.

If wet or damp weather continues after infection, the entire plant quickly decays, giving off the somewhat musty odour so characteristic of dying potato vines. At first, the attack is insignificant, only affecting a leaf or stem here and there, and the danger is not immediately realized, but the disease can spread so rapidly that, in a matter of hours, an apparently healthy field may be severely damaged or completely destroyed.

FIGURE 1.—Late blight on potato leaf.

On the Tubers, the disease appears in the form of a dry rot, and is first seen as a purplish-brown discoloration of the skin, particularly in and around the eyes. Upon cutting such tubers, a dry, granular, and brownish or reddish rot is found beneath the invaded skin area, and penetrating a short distance into the tuber.

The affected parts of the tubers die and shrink, causing irregular sunken spots over the surface. The organism itself produces a dry rot, but organisms occurring in the soil or in damp surroundings may gain entrance through the diseased areas and cause secondary wet rots, which may then mask the typical symptoms of late blight rot. The dry rot spots may be evident at digging time, but, under dry conditions, slightly infected tubers may escape notice. During the early part of the storage period, the infected parts become more evident, especially when the tubers are placed under storage conditions of high temperature and moisture, and poor ventilation.

FIGURE 2.—Late blight tuber rot.
A. External symptoms B. Internal symptoms

The Cause of Late Blight

Late blight is caused by the fungus *Phytophthora infestans* (Mont) de Bary, one of the downy mildews. A fungus is a plant, but it lacks chlorophyll, the green colouring matter of the higher plants, which is essential for the manufacture of plant food. Every fungus, then, must obtain its food directly from living or dead vegetable or animal matter. The blight fungus derives its food from the living potato plant and its tubers. It is, therefore, a true parasite, and is responsible for the condition known as late blight and late blight tuber rot. To understand better how this fungus behaves and the measures necessary to control it successfully, its life cycle and habits are explained more fully below.

When a diseased potato is planted, the fungus, which consists of very fine thread-like tubes between the cells of the tuber, begins to grow as the potato begins to produce sprouts. It then invades the new sprouts. It forms dark brown to black elongated spots on the sprouts or stems of the potato plants at or slightly above the surface of the soil. When the weather turns warm and moist, fine fungus threads of slightly different shape to those inside the plant appear at the surface of these spots and produce at their tips spores (the "seed"

of the fungus). The spores are so small that they can be seen individually only under a microscope. These threads and spores form the greyish mildew, mentioned under Symptoms. If the weather is warm and moist, the fungus continues to spread, reaching out for more nourishment and destroying the invaded plant tissue.

The spores are splashed about by rain or blown around by wind. If they fall upon a potato leaf, and moisture is present, they germinate and send germ tubes into the plant tissue and start new infections. In a matter of hours, fine fungus threads in large numbers again appear on the lower surface of the leaf and produce additional spores. Under favourable conditions, these spores cause additional infections, and thus the disease continues rapidly to spread and destroy. A potato field unprotected by fungicides can be entirely killed in two or three days.

In addition to spreading the disease among the plants, countless numbers of spores may be washed down by rain into the soil, and, coming in contact with the tubers, penetrate the skin and cause the late blight tuber rot. The fungus overwinters in slightly affected tubers, which, if planted the next spring, will start the disease in the resulting crop. It does not overwinter in the soil.

Thus, it must be realized that the late blight fungus spends the greater part of its existence within the plant itself, where it is afforded a high measure of safety; but the tiny spores, which spread the disease, do not have this same protection, and hence the fungus is vulnerable at this stage in its life cycle. The control of the disease by spraying or dusting the plants is based on the fact that the chemicals used are toxic to the spores. It follows then that, if the plants are sprayed or dusted *before* infection has taken place, the spores that fall on the plants are killed when they come in contact with the chemical, and infection is prevented. Control, therefore, is obtained by protecting the plants from infection — a principle that must be kept in mind in conducting a blight control program.

Combating Late Blight

Sanitation.—Tubers showing signs of rot should not be used for planting. If tubers infected with late blight are planted, the fungus may grow up inside the young sprouts, killing many of them, but in others it will reach the above ground parts and there cause the black elongated stem lesions, as described under Symptoms. Under favourable conditions of moisture and temperature, spores will be produced on these lesions, wind and rain will spread them to other potato plants, and the disease will become established. Similarly, late blight can develop on sprouts from diseased tubers discarded in the spring and spread from there by wind-borne spores to nearby potato fields. The earliest late blight infections observed in potato fields have been traced to such sources. All cull potatoes should therefore be destroyed.

There are several ways of dealing with the cull pile menace. Tubers that are being discarded during the winter may be scattered in thin layers outdoors, where they will be destroyed by frost. Small lots of cull potatoes may be satisfactorily disposed of in the spring by deep burial or by baking them. The latter method involves placing thin layers alternately with combustible material and setting the pile on fire. If tubers in refuse heaps have sprouted, any one of several different kinds of herbicides, or weed killers, can be used to kill the sprouts. These herbicides usually kill the eyes also, thus preventing any further sprouting. However, when the cull pile is deep, more than one application may be needed to kill the buried sprouts. The important point to

remember is that the cull piles should be treated early and effectively, and thereafter examined periodically for new sprouts. If any appear, another treatment should be applied.

Spraying.—Spraying (or dusting) the plants with copper compounds, or other approved fungicides, is the most important factor in blight control, but thoroughness and timeliness of application are essential for success. Even if all the potatoes planted on a farm are free from blight, it is necessary to spray them, as the disease may be brought into the fields by wind-blown spores from a neighbouring farm. It is known that late blight overwinters in the southern United States, where potatoes are grown during the winter, and that the disease spreads northward by wind-borne spores from potato field to potato field as the season advances. Spraying as a preventive is, therefore, absolutely essential for the control of late blight, at least until resistant varieties become available.

Bordeaux mixture is the standard spray, and for many years the formula 10-10-100 has been followed in the preparation of this widely used potato spray. This formula calls for 10 pounds of copper sulphate (bluestone), 10 pounds of the best hydrated lime, and 100 gallons of water. Experiments conducted at Charlottetown, P.E.I., for several years, have shown that the lime may be safely reduced to one-half the amount formerly recommended and that this reduction has many advantages. The formula 10-5-100 is now recommended for preparing bordeaux mixture for potatoes. The chief advantages are: it rarely clogs the sprayer nozzles; it acts quickly and effectively; it costs less; and it leaves less lime on the plants than does the 10-10-100 mixture. Besides, the smaller amount of lime favours higher yields.

There are on the market "fixed" copper compounds which are sold under trade names, such as Basi-Cop, Bordow, Copper-A, C.O.C.S., Cuprocide, Genicop, Gy-Cop Perenox, Deecop, etc. These fungicides contain no lime. Lime is considered by some authorities to be detrimental to the growth of the potato plant. In addition to being highly efficient in their action against blight, these products are very convenient to use, as it is only necessary to add the right amount to the spray tank while the agitators are running. Moreover, they leave little sediment on the leaves.

More recently, organic fungicides for use on potatoes have been introduced. A considerable number of them are being tested in both Canada and the United States, and a few of them have so far given good results in many regions. These are sold under trade names, such as Dithane, Karbam White, Parzate, and Zerlate. In using these products, the manufacturers' directions should be followed. Growers should, however, find out what fungicides are recommended for their own locality.

Spraying is more important in some regions that in others. In some localities, particularly in coastal regions, a full season spray program is required to control blight successfully, from five to nine applications being necessary. In other areas that are not so subject to frequent rains or fogs, fewer spray applications may suffice. In any case, growers are advised to consult with the nearest plant pathological laboratory as to the timing of their applications of sprays or dusts. In some regions, an advisory service is conducted by the pathologists. Through this service, growers are advised by press and radio bulletins of the incidence and the probable spread of late blight in the various districts, and advice relating to spray applications is timed according to the severity of the disease and the weather conditions likely to favour its spread. Growers would be wise to avail themselves of such a service.

For a spraying program to be successful in controlling late blight, the suggestions given below should be closely followed.

1. Early application. The first spray should be applied when the plants are not more than eight inches high, in order to ensure that the lower leaves are well covered with the fungicide.

2. Regular applications. Spraying should be done every ten days, and, if blight is developing rapidly and moist weather prevails, the interval should be reduced to seven, preferably to five, days.

3. Applications before rain. Blight develops rapidly during wet weather, and, in order to give protection to the plants over a wet period, the sprays should be applied, if at all possible, before rains. The plants, however, should not be sprayed when it is raining or when they are wet.

4. Applications during fine weather. Spraying should not be neglected during fine weather or during the haying period. Spraying is a preventive measure (an insurance against infection), and should never be neglected.

5. Maintenance of schedule. Maintain the spray schedule until the end of the season. It is a common practice for growers to spray thoroughly and frequently early in the season, but later, when the spray material applied in the early season has been largely washed off and blight begins to spread, the fields are neglected and heavy losses result.

6. Satisfactory performance of sprayer. Pay strict attention to the performance of the sprayer. Clogged nozzles, low and uneven pressure, or other defects, result in poor coverage. Renew nozzle disks as soon as they begin to show wear.

7. Proper preparation of spray. The directions for preparing the spray mixture should be followed carefully. This advice applies not only to bordeaux mixture, but also to commercial products.

8. Maintenance of pressure. Maintain a pressure of at least 250 pounds, higher if possible, not only in the main part of the field, but also at the end of the rows.

9. Thoroughness of the application. Spray the rows in both directions in districts where late blight is generally severe, so as to ensure complete coverage.

Dusting.—Copper-lime dusts or neutral copper dusts are used by many potato growers instead of the liquid mixtures. Advocates of dusting draw attention to the lower labour costs, reduced depreciation of machinery, ease of operation, and speed of application.

Investigations at Charlottetown have shown that dusting compares favourably with liquid spraying, except in bad blight years. In such years, dusts have not proved satisfactory. Under the severe blight conditions of 1948, it was apparent that the results were in favour of spraying, as will be seen by an examination of Table 1.

From twenty to forty pounds of dust per acre should be applied, the actual amount depending on the percentage of copper in the dust, the size of the plants, and the severity of the disease. Most commercial dusts contain either 6 per cent or 7 per cent of copper, so that the difference in rates of application on this basis is not great. Twenty pounds per acre is sufficient when the plants are small, but the amount should be gradually increased as the plants grow and fill in the rows. Because, for a given area, the cost of materials for dusting is greater than that for spraying, there is a tendency on the part of many growers

to use a minimum amount of dust, and, consequently, the copper dosage per acre is usually less when dusting is practised. Bordeaux mixture spray, used at a rate of from 80 to 100 gallons per acre, will give a copper dosage of from 2·0 to 2·5 pounds per acre. To equal this dosage, it would require from 28·6 to 37·7 pounds per acre of a 7 per cent copper dust and from 33·3 to 41·7 pounds per acre of a 6 per cent copper dust.

TABLE 1.—EFFECTS OF DUSTING AND SPRAYING ON YIELD OF TUBERS AND ON CONTROL OF LATE BLIGHT ROT, 1948

Chemical	Method	Total yield per acre	Marketable tubers[1]	Loss from tuber rot
		bu.	bu.	%
Copper sulphate lime	Dust	199·5	163·9	5·2
	Spray	256·9*	232·1	3·5
Copper oxychloride sulphate	Dust	249·1*	215·4	5·5
	Spray	260·0*	237·0	2·8
Tetra copper calcium oxychloride	Dust	232·4	196·5	5·6
	Spray	248·0*	225·9	2·7
Check	.....	167·5	129·1	6·4

[1] Total yield less undersized and rotted tubers.
* Indicates significant difference at the 5 per cent level as compared with check plot.
Least significant difference at the 5 per cent level=72·05 bushels per acre.

In using dust for blight control, the following suggestions should prove valuable:—

1. Ensure the maximum discharge by preventing the dust from "caking" in the bottom of the hopper or in the entrance to the delivery tube. Caking is likely to occur if the hopper is completely filled.

2. Applications should be made in the evening, or early in the morning. At these times, strong winds are not likely to interfere, and the dew on the plants enables the dust to adhere.

3. In driving, turn away from the dust cloud. Begin on the leeward side of the field and at the end of each row turn out of the cloud of dust which has just been discharged. This precaution will add greatly to the comfort of the operator and the team.

Cultivation and Hilling.—The presence of weeds in a potato field will interfere with the proper dispersal of the dust or the spray solution and prevent the complete coverage of the plants with the fungicide. Adequate and timely cultivation when the weeds are small will easily control them and thus obviate this trouble.

The rows should be kept thoroughly hilled up in order to provide a thick soil covering over the tubers throughout the season. Hilling will give the maximum protection against infection by late blight spores that may be washed down by the rain, and will also reduce losses from sunburn and frost.

It used to be customary to have the rows close together, so that the hills had to be steep and pointed. The steeply inclined sides of the hills shed most of the water during rains, and, during dry weather, increased the evaporation from their slopes. This type of hill probably diminished the yields, the plants not being able to get sufficient water for their proper development. More

recently, the rows are usually spaced from 36 to 40 inches apart, thereby permitting a broader, less steeply inclined hill, with a reasonably broad, slightly concave crown to be made. This type of hill absorbs much of the rain, is less subject to moisture loss through evaporation, and provides the maximum depth of soil covering.

In "heavy" soils that crack when dry, it is almost impossible to grow susceptible varieties free from tuber rot, no matter how well sprayed they are, as spores are very likely to be washed down into the cracks by rain and infect the tubers. Potatoes should be grown only on the lighter soils, at least until resistant varieties are available.

Killing Potato Tops to Prevent Tuber Infection.—Both experiments and experience leave no doubt as to the necessity for destroying potato tops about two weeks before digging in order to prevent tuber rot, even though a full spray program has been carried out. This practice is necessary because some late blight spores will be produced on the potato plants as long as they remain green, in spite of the most careful and thorough spraying, and these spores can infect the tubers. Killing the tops two weeks before harvesting will assure that no viable spores will be present to infect the tubers when they are being dug. The tops may be killed by pulling them by hand or by mowing them, but the most practical means is by spraying or by dusting them with a chemical top killer. A number of materials, manufactured for this purpose, are now on the market.

FIGURE 3.—Potato tops destroyed by a chemical spray.

The material that has given the most satisfactory results so far is sodium arsenite, which is sold as a concentrated solution.[1] Although a deadly poisonous substance, and requiring the usual safety precautions, it does not affect the potato tubers when it is sprayed on the vines at the recommended strength. Two quarts of a sodium arsenite top killer added to 80 gallons of water make a

[1] Adam's Handy Killer, Green Cross Top Killer, and Geigy's Potato Vine Killer are examples of arsenical top killers.

spray strong enough to kill plants that are ripening, but, when the plants are quite green and vigorous, 3 or even 4 quarts may be required. It is recommended that the sprayer be driven both up and down the rows, that is, in both directions, in order to cover the plants more completely with the spray and to ensure a more effective destruction of the vines, especially if an old and not very efficient sprayer is used. A combination spray of sodium arsenite and oil is still more effective, and is prepared by stirring the sodium arsenite top killer and oil[1] together, adding the resulting mixture to the sprayer tank, and finally adding the water while the agitators are turning. Excellent results have been obtained at Charlottetown, P.E.I., when the vines were sprayed with a mixture containing 2 quarts of a sodium arsenite top killer and 4 gallons of oil per 80 gallons of water. Recent tests have shown that the addition of common salt also increases the effectiveness of sodium arsenite sprays. The salt may be added at a rate of from 8 to 16 pounds for each 80 gallons of spray.

Bluestone (copper sulphate) solutions have never proved satisfactory, the killing rate being too slow, but this material may be used when more effective ones are not available. An 80-gallon mixture should contain 30 pounds of bluestone and 10 pounds of common salt. Potato plants that have been sprayed all summer with bordeaux mixture appear to acquire a tolerance for bluestone, and the amount necessary for completely killing the tops is consequently high.

Other top killers are available, and, when used according to the manufacturers' directions, are quite satisfactory. These are complex dinitrophenols, dinitrocresols, etc., and are sold under such trade names as Dow 66 Improved, Sinox, and Krenite. These "dinitro" compounds are more likely to cause stem-end discoloration than is sodium arsenite, bluestone, or cyanamid. It is advisable to consult the local plant pathological laboratory to find out what top killers are recommended for the district concerned.

Dusting with powdered cyanamid has also given good results. This dust has to be applied with a power duster and two applications of 50 pounds per acre, a few days apart, are necessary. The cyanamid increases the fertility of the soil, as it contains 21 per cent nitrogen; but it is a very caustic chemical and, if the duster is not cleaned thoroughly immediately following the application, corrosion of the metal parts will occur. Sand, free from gravel or rock particles, blown through the duster will clean it effectively and obviate this type of depreciation.

Machines that cut off the tops near to the ground level and shred them into small pieces, are now being manufactured and are becoming popular in some districts. These machines are powered by the tractor take-off and are drawn behind tractors. However, they are expensive, and, therefore, do not appear to be economical for the small grower, but in some localities their operation on a custom basis may be possible.

Delayed Digging.—Blight spores can survive on the surface of the soil for several days, occasionally as long as fourteen days, and, if they come in contact with tubers dug at any time during that period, they may infect them. To make matters worse, the tubers may appear to be perfectly healthy when stored, but later may become infected by spores brought in on their surface. Severe losses frequently result in storage bins from such infection. It is much safer, whenever possible, to leave the crop undug for fourteen days after the vines have died, or have been killed by frost or a chemical. During that time, the spores on the dead vines and on the soil will perish; and most of the tubers that became

[1] Waste crankcase oil, diesel oil, fuel oil, etc.

infected during the season by spores washed into the soil by rain will show the rot and can be detected and discarded. As mentioned earlier, the killing of the vines largely removes the danger of infection in storage.

Whether or not late blight is present on the foliage, it is advisable to leave the tubers in the ground for a number of days after the tops are dead. During this period, the tubers loosen from the stolons and the skin matures, or toughens, rendering the potatoes less susceptible to mechanical injury during digging and subsequent handling. Tubers harvested in an immature condition are easily bruised, even by light blows. Injured tubers are more likely than uninjured ones to be attacked in storage by certain other rots.

Blight Resistant Varieties.—Very encouraging advances have been made towards a solution of the late blight problem by breeding resistant varieties. This objective will be fully realized when resistant varieties, adapted to each potato producing region and of the type and quality demanded by the public, have been developed. In Canada, as the result of a co-operative project between the Dominion Experimental Station and the Dominion Laboratory of Plant Pathology at Fredericton, N.B., promising blight resistant potatoes have already been produced. These are now being multiplied for extensive trials throughout the country.

Preparation of Bordeaux Mixture

Bordeaux mixture may be made by either of two methods, namely, the stock solution method and the instant method. The instant method saves time and is more satisfactory, but calls for powdered copper sulphate, fine hydrated lime, and a sprayer with power-driven agitators. Hydrated lime held over from the previous year is not satisfactory for spray purposes.

Stock solution method.—Two containers, one for the copper sulphate and one for the lime, are required. Wooden casks are preferable and under no circumstances should a metal container be used. The copper sulphate, one pound for each gallon of water in the container, is suspended in a bag so that it is not entirely submerged in the water. When it has dissolved, the liquid will contain one pound of copper sulphate per gallon. The cask must be kept covered to prevent the evaporation of the water, and the solution must be stirred well before mixing each batch of bordeaux.

A similar stock solution of hydrated lime can be made up by thoroughly stirring one pound of the lime to each gallon of water in the other cask. If quicklime is used, it should be weighed out and slaked in the cask, care being taken to add the water gradually so as to get the greatest amount of heat and, consequently, the finest possible quality of lime. When boiling ceases, add enough water to give a stock solution containing one pound of lime per gallon. This cask, too, must be kept covered and the contents thoroughly stirred before the lime is measured out. The stock solution of lime rapidly degenerates and quickly becomes useless for spraying. A fresh batch should, therefore, be prepared each time potatoes are to be sprayed.

To prepare 100 gallons of 10-5-100 bordeaux mixture by the stock solution method, proceed as follows:

1. Pour 80 gallons of water into the spray tank.
2. Stir in 10 gallons of stock copper sulphate.
3. Stir in 5 gallons of the stock lime.[1]
4. Add sufficient water to make up the full 100 gallons.

[1] The hydrated lime now on the market is usually so good that the stock lime solution need not be prepared. Five pounds of lime may be weighed, mixed with water in a bucket, stirred into a creamy paste, and then strained directly into the spray tank.

Instant Bordeaux.—To prepare 100 gallons of 10-5-100 bordeaux mixture by the instant method, proceed as follows:

1. While the tank is being filled with water, keep the agitators turning, and sift in 10 lb. of pulverized copper sulphate. Allow about 5 minutes for it to dissolve.

2. When the tank is nearly full, sift in 5 lb. of fine hydrated lime.

3. Add sufficient water to make up the full 100 gallons.

4. Keep the agitators running during the whole mixing operation.

Dolomitic hydrated lime may be substituted for the ordinary calcium hydrated lime in the preparation of bordeaux mixture for spraying potatoes in areas where magnesium deficiency occurs or is likely to occur.

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